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ST. LOUIS RESERVOIR, GRATIOT COUNTY, MICHIGAN

Pacific Northwest Environmental Research Laboratory

Prepared for:

National Environmental Research Center
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16. ABSTRACT
Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivded according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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REPORT

ON

ST. LOUIS RESERVOIR

GRATIOT COUNTY

MICHIGAN

EPA REGION V

WORKING PAPER No. 212

WITH THE COOPERATION OF THE

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

AND THE

MICHIGAN NATIONAL GUARD

MARCH, 1975

CONTENTS

	Page
Foreword	ii
List of Michigan Study Lakes	iv
Lake and Drainage Area Map	v
Sections	
I. Conclusions	1
II. Lake and Drainage Basin Characteristics	4
III. Lake Water Quality Summary	5
IV. Nutrient Loadings	8
V. Literature Reviewed	13
VI. Appendices	14

FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Michigan Department of Natural Resources for professional involvement and to the Michigan National Guard for conducting the tributary sampling phase of the Survey.

A. Gene Gazlay, former Director, and David H. Jenkins, Acting Director, Michigan Department of Natural Resources; Carlos Fetterolf, Chief Environmental Scientist, Bureau of Water Management; and John Robinson, Chief, Dennis Tierney, Aquatic Biologist, and Albert Massey, Aquatic Biologist, Water Quality Appraisal Section, Bureau of Water Management, Department of Natural Resources, provided invaluable lake documentation and counsel during the course of the Survey. John Vogt, Chief of the Bureau of Environmental Health, Michigan Department of Public Health, and his staff were most helpful in identifying point sources and soliciting municipal participation in the Survey.

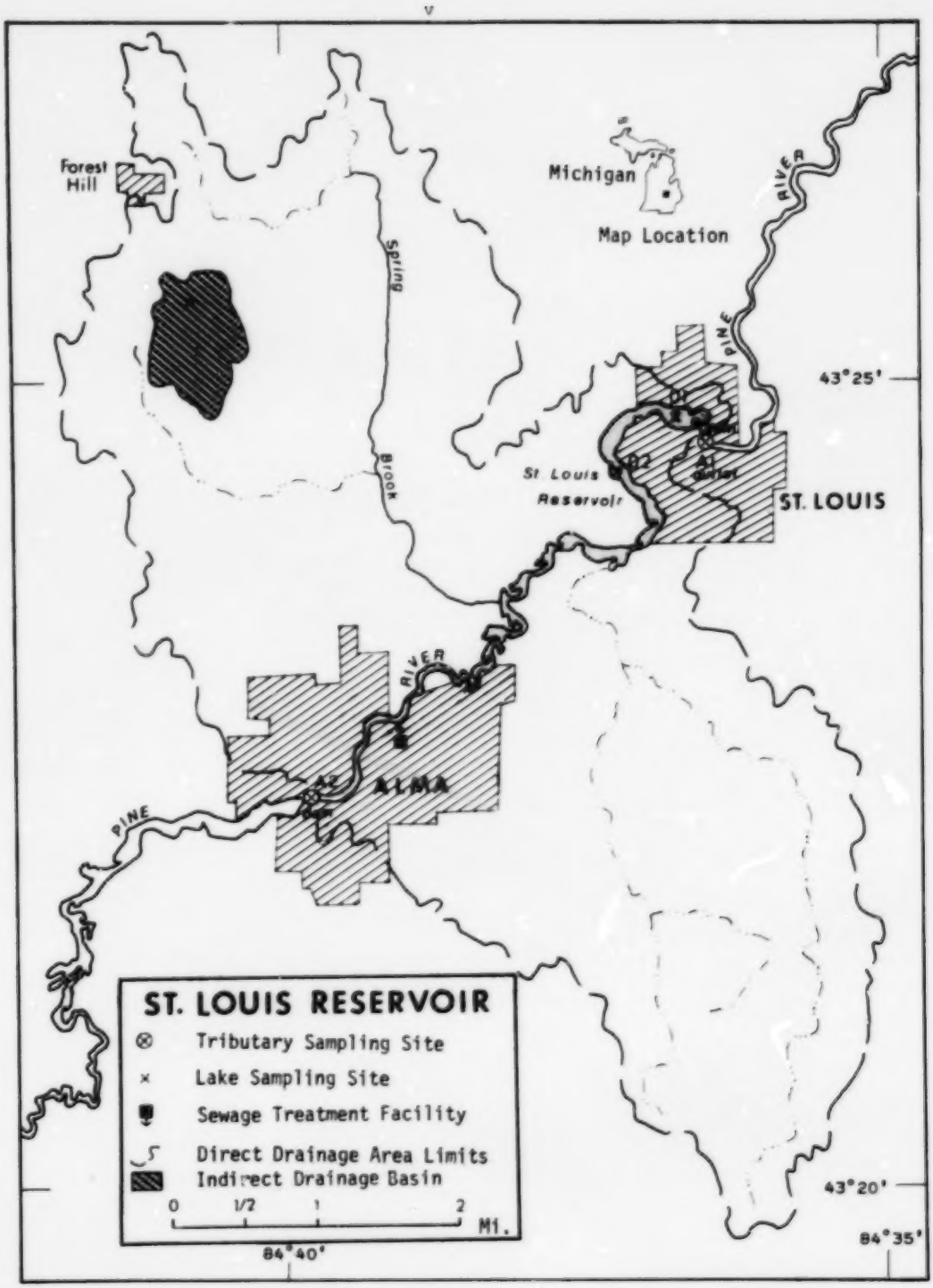
Major General Clarence A. Schnipke (Retired), then the Adjutant General of Michigan, and Project Officer Colonel Albert W. Lesky, who directed the volunteer efforts of the Michigan National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF MICHIGAN

LAKE NAME	COUNTY
Allegan Res.	Allegan
Barton	Kalamazoo
Belleville	Wayne
Betsie	Benzie
Brighton	Livingston
Caro Res.	Tuscola
Charlevoix	Charlevoix
Chemung	Livingston
Constantine Res.	St. Joseph
Crystal	Montcalm
Deer	Marquette
Ford	Washtenaw
Fremont	Newago
Higgins	Roscommon
Holloway Res.	Genesee, Lapeer
Houghton	Roscommon
Jordon	Ionia, Barry
Kent	Oakland
Long	St. Joseph
Macatawa	Ottawa
Manistee	Manistee
Mona	Muskegon
Muskegon	Muskegon
Pentwater	Oceana
Pere Marquette	Mason
Portage	Houghton
Randall	Branch
Rogers Pond	Mecosta
Ross	Gladwin
St. Louis Res.	Gratiot
Sanford	Midland
Strawberry	Livingston
Thompson	Livingston
Thornapple	Barry
Union	Branch
White	Muskegon


Forest Hill
Spring Brook
Michigan
Map Location
PINE RIVER
43°25'
St. Louis Reservoir
ST. LOUIS
PINE RIVER
ALMA
PINE
43°20'
84°35'
84°40'
ST. LOUIS RESERVOIR
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
Direct Drainage Area Limits
Indirect Drainage Basin
0 1/2 1 2 Mi.

ST. LOUIS RESERVOIR

STORET NO. 2693

I. CONCLUSIONS

A. Trophic Condition:

Survey data and the records of others (Robinson, 1970) show that St. Louis Reservoir is eutrophic. Of the 35 Michigan lakes sampled in November when essentially all were well-mixed, 28 had less mean total and dissolved phosphorus, and 24 had less mean inorganic nitrogen; of the 41 lakes sampled, 34 had greater mean Secchi disc transparency, but only eight had less mean chlorophyll a.

Survey limnologists observed an algal bloom in progress in June and noted the occurrence of rooted aquatic vegetation in the shallower areas of the reservoir.

B. Rate-Limiting Nutrient:

A significant loss of phosphorus occurred in the assay sample between the time of collection and the beginning of the assay, and the results are not representative of conditions in the reservoir at the time the sample was taken.

The reservoir data indicate nitrogen limitation in June and September but phosphorus limitation in November.

C. Nutrient Controllability:

1. Point sources--During the sampling year, St. Louis Reservoir received a total phosphorus load at the extremely high rate

* See Appendix A.

of 1,030 lbs/acre/yr or 115.4 g/m^2/yr. This rate is 36 times the rate proposed by Vollenweider (in press) as "dangerous"; i.e., a eutrophic rate (see page 12). However, Vollenweider's model probably is not applicable to water bodies with short hydraulic retention times, and the hydraulic retention time of St. Louis Reservoir is certain to be very short. For example, the maximum depth sampled during the Survey was four feet; and, if the mean depth of the reservoir also is four feet, the mean hydraulic retention time would be a very short 1½ days. It is very likely then, that Vollenweider's model does not apply to this reservoir.

It is calculated that the City of Alma contributed just over 69% of the total phosphorus load to the reservoir during the sampling year. While even complete removal of phosphorus at this source would still leave a loading rate of about 35.6 g/m^2/yr, considering the very short hydraulic retention time of the reservoir, it is possible that a high degree of phosphorus removal at Alma would result in a persistent phosphorus limitation (see page 7) and a reduction in the incidence and severity of nuisance algal blooms. However, it appears that a marked improvement of the trophic condition of the reservoir will require reduction of phosphorus loads from other sources as well (see below).

It appears that industrial wastes, such as food-processing wastes, may have been contributing significant nutrient loads to the Alma plant during the sampling year. The population of Alma is about 9,700, but the effluent phosphorus population equivalent was over 45,000, and the effluent nitrogen population equivalent was 19,300.

It is noted that construction of secondary treatment facilities, including phosphorus removal, was underway at Alma during the Survey sampling year (Kooistra, 1973).

2. Non-point sources--During the sampling year, the non-point phosphorus export rate of the Pine River was a very high 172 lbs per square mile of drainage area (see page 12), and the export N/P ratio of 18/1 is indicative of point sources beyond the 25-mile limit of the Survey*. However, Robinson (1970) notes that the upper half of the Pine river watershed, above Alma, is used mainly for agricultural purposes.

Whatever the cause of the high phosphorus export rate, the very high drainage area to reservoir area ratio of 1,554 to 1 will ensure a high phosphorus load to St. Louis Reservoir even with a moderate export rate, and all phosphorus inputs to the reservoir should be minimized to the greatest practicable degree.

* See Working Paper No. 1, "Survey Methods, 1972".

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

A. Lake Morphometry:

1. Surface area: 158 acres†.
2. Mean depth: unknown.
3. Maximum depth: unknown.
4. Volume: unknown.
5. Mean hydraulic retention time: unknown.

B. Tributary and Outlet:
(See Appendix B for flow data)

1. Tributaries -

Name	Drainage area*	Mean flow*
Pine River	286.0 mi^2	198.0 cfs
Minor tributaries & immediate drainage -	24.8 mi^2	10.0 cfs
Totals	310.8 mi^2	208.0 cfs

2. Outlet -

Pine River	311.0 mi^2**	208.0 cfs**

C. Precipitation***:

1. Year of sampling: 34.9 inches.
2. Mean annual: 28.4 inches.

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† Fetterolf, 1973.
* Drainage areas are accurate within ±5%; mean daily flows for 74% of the sampling sites are accurate within ±25% and the remaining sites up to ±40%; and mean monthly flows, normalized mean monthly flows, and mean annual flows are slightly more accurate than mean daily flows.
** Includes area of lake; flow adjusted to equal sum of inflows.
*** See Working Paper No. 1.

III. LAKE WATER QUALITY SUMMARY

St. Louis Reservoir was sampled three times during the open-water season of 1972 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from two stations on the reservoir (see map, page v). During each visit, a single depth-integrated (near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the second visit, a single five-gallon depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depth sampled at station 1 was 4 feet; only near-surface samples were collected at station 2.

The results obtained are presented in full in Appendix C, and the data for the fall sampling period, when the lake essentially was well-mixed, are summarized below. Note, however, the Secchi disc summary is based on all values.

For differences in the various parameters at the other sampling times, refer to Appendix C.

A. Physical and chemical characteristics:

FALL VALUES

(11/14/72)

Parameter	Minimum	Mean	Median	Maximum
Temperature (Cent.)	4.0	4.0	4.0	4.0
Dissolved oxygen (mg/l)	11.5	11.5	11.5	11.5
Conductivity (μmhos)	590	790	890	890
pH (units)	7.8	7.8	7.8	7.9
Alkalinity (mg/l)	159	200	212	228
Total P (mg/l)	0.016	0.134	0.120	0.265
Dissolved P (mg/l)	0.009	0.093	0.072	0.199
NO_2 + NO_3 (mg/l)	0.280	0.983	1.280	1.390
Ammonia (mg/l)	0.060	0.243	0.210	0.460
		ALL VALUES		
Secchi disc (inches)	24	37	39	50

B. Biological characterisitics:

1. Phytoplankton* -

Sampling Date	Dominant Genera	Number per ml
09/17/72	1. Fragilaria	530
	2. Cyclotella	458
	3. Synedra	410
	4. Navicula	361
	5. Achnanthes	205
	Other genera	1,072
	Total	3,036
11/14/72	1. Synedra	137
	2. Raphidiopsis	128
	3. Lyngbya	116
	4. Navicula	92
	5. Achnanthes	88
	Other genera	319
	Total	880

* The June sample was lost in shipment.

2. Chlorophyll *a* -
(Because of instrumentation problems during the 1972 sampling, the following values may be in error by plus or minus 20 percent.)

Sampling Date	Station Number	Chlorophyll *a* (µg/l)
06/14/72	01	19.1
	02	10.5
09/17/72	01	1.0
	02	1.0
11/14/72	01	1.2
	02	0.7

C. Limiting Nutrient Study:

There was a 53% loss of phosphorus in the assay sample between the time of collection and the beginning of the assay, and the results are not representative of conditions in the reservoir at the time the sample was taken (09/17/72). Had the loss not occurred, the expected control yield of the test alga, *Selenastrum capricornutum*, would have been a very high 54 mg/l (dry weight) based on the yields obtained in other assays with similar nutrient concentrations.

The reservoir data indicate nitrogen limitation in June (N/P ratio = 2/1) and September (N/P = 7/1) but probable phosphorus limitation in November (N/P = 14/1).

IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Michigan National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of March and May when extra samples were collected. Sampling was begun in October, 1972, and was completed in October, 1973.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Michigan District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Since no unimpacted tributaries were sampled, the nutrient loadings for "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S) were estimated by using the means of the nutrient loads, in lbs/mi^2/year, in tributaries to nearby Holloway Reservoir at stations B-1 and F-1 and multiplying the means by the ZZ area in mi^2.

The operator of the Alma wastewater treatment plant provided monthly effluent samples and corresponding flow data.

No industrial effluents were sampled.

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* See Working Paper No. 1.

A. Waste Sources:

1. Known municipal† -

Name	Pop. Served*	Treatment	Mean Flow (mgd)	Receiving Water
Alma	9,790	prim. clarifier	2.439	Pine River

2. Known industrial** -

Name	Treatment	Mean Flow (mgd)	Receiving Water
Leonard Refineries, Alma	?	?	Pine River
Lobdell-Emery & Alma Products, Alma	?	?	Pine River
Michigan Chemical Co.	?	?	Pine River

† Kooistra, 1973.
* 1970 Census.
** Robinson, 1970.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	lbs P/ yr	% of total
a. Tributaries (non-point load) -		
Pine River	49,250	30.3
b. Minor tributaries & immediate drainage (non-point load) -	860	0.5
c. Known municipal STP's -		
Alma	112,570	69.2
d. Septic tanks* -	?	-
e. Known industrial -		
Leonard Refineries	?	-
L-E & A Products	?	-
Michigan Chemical	?	-
f. Direct precitation** -	20	<0.1
Total	162,700	100.0

2. Outputs -

Lake outlet - Pine River 156,160

3. Net annual P accumulation - 6,540 pounds

* Probably insignificant.
** See Working Paper No. 1.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	lbs N/ yr	% of total
a. Tributaries (non-point load) -		
Pine River	889,560	82.6
b. Minor tributaries & immediate drainage (non-point load) -	41,640	3.9
c. Known municipal STP's -		
Alma	144,890	13.4
d. Septic tanks* -	?	-
e. Known industrial -		
Leonard Refineries	?	-
L-E & A Products	?	-
Michigan Chemical	?	-
f. Direct precipitation** -	1,520	0.1
Total	1,077,610	100.0

2. Outputs -

Lake outlet - Pine River 1,157,460

3. Net annual N loss - 79,850 pounds

* Probably insignificant.
** See Working Paper No. 1.

D. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	lbs P/mi^2/yr	lbs N/mi^2/yr	N/P Ratio
Pine River	172	3,110	18/1

E. Yearly Loading Rates:

In the following table, the existing phosphorus loading rates are compared to those proposed by Vollenweider (in press). Essentially, his "dangerous" rate is the rate at which the receiving water would become eutrophic or remain eutrophic; his "permissible" rate is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic rate would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with very short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
lbs/acre/yr	1,029.7	41.4	6,820.3	loss*
grams/m^2/yr	115.42	4.64	764.4	-

Vollenweider loading rates for phosphorus (g/m^2/yr) based on surface area and mean outflow of St. Louis Reservoir:

"Dangerous" (eutrophic rate)	3.20
"Permissible" (oligotrophic rate)	1.60

* There was an apparent loss of nitrogen from St. Louis Reservoir during the sampling year. This may have been due to nitrogen fixation in the reservoir, solubilization of previously sedimented nitrogen, recharge with nitrogen-rich ground waters, or more probably, the unsampled industrial discharges to the reservoir.

V. LITERATURE REVIEWED

Fetterolf, Carlos, 1973. Personal communication (area of lake). MI Dept. Nat. Resources, Lansing.

Kooistra, Ronald D., 1973. Treatment plant questionnaire (Alma STP and improvements under construction). MI Dept. Publ. Health, Lansing.

Robinson, John G., 1970. Biological survey of the Pine River, vicinity of Alma and St. Louis. MI Dept. Nat. Resources, Lansing.

Vollenweider, Richard A. (in press). Input-output models. Schweiz. Z. Hydrol.

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	FALL VALUES MEAN TOTAL P	FALL VALUES MEAN DISS P	FALL VALUES MEAN INORG N	ALL VALUES 500-MEAN SEC	ALL VALUES MEAN CHLORA	ALL VALUES 15-MIN UO
2640	HOLLOWAY RESERVOIR	0.062	0.043	1.461	439.375	10.678	9.200
2641	CARO RESERVOIR	0.117	0.022	3.835	473.000	11.967	9.500
2642	BOARDMAN HYDRO POND	0.086	0.005	0.358	363.500	1.267	6.600
2603	ALLEGAN LAKE	0.123	0.057	1.168	478.222	20.311	12.600
2606	BARTON LAKE	0.121	0.086	1.489	456.167	27.800	14.850
2609	BELLEVILLE LAKE	0.118	0.048	1.420	469.250	28.262	8.200
2610	BETSIE LAKE	0.025	0.008	0.273	461.667	4.567	7.400
2613	BRIGHTON LAKE	0.109	0.073	1.015	456.000	44.233	7.500
2617	LAKE CHARLEVOIX	0.007	0.006	0.230	351.250	3.008	9.240
2618	LAKE CHEMUNG	0.044	0.014	0.132	484.333	13.483	14.800
2621	CONSTANTINE RESERVOIR	0.027	0.008	0.910	456.167	39.317	7.500
2629	FORD LAKE	0.105	0.058	1.536	456.167	14.733	14.000
2631	FREMONT LAKE	0.372	0.342	1.408	441.667	28.500	14.800
2640	JORDAN LAKE	0.188	0.144	1.998	427.667	20.517	14.900
2643	KENT LAKE	0.040	0.015	0.417	495.800	33.954	13.000
2648	LAKE MACATAWA	0.197	0.120	2.358	477.600	25.600	12.200
2649	MANISTEE LAKE	0.018	0.010	0.304	451.333	6.317	11.300
2659	MUSKEGON LAKE	0.087	0.043	0.469	436.444	9.511	14.800
2665	PENTWATER LAKE	0.027	0.017	0.496	430.667	16.083	14.800
2671	RANDALL LAKE	0.246	0.183	0.810	457.333	27.217	8.020
2672	ROGERS POND	0.026	0.015	0.183	435.500	8.133	9.600
2673	RUSS RESERVOIR	0.034	0.021	0.460	465.333	10.383	8.200
2674	SANFORD LAKE	0.016	0.008	0.307	458.750	13.791	8.300
2683	THORNAPPLE LAKE	0.042	0.032	1.737	442.833	14.650	10.800
2685	UNION LAKE	0.083	0.064	1.252	455.500	15.667	8.200
2688	WHITE LAKE	0.027	0.019	0.367	417.778	9.211	13.400
2691	MONA LAKE	0.307	0.241	0.963	451.667	27.783	14.100
2692	LONG LAKE	0.163	0.148	0.749	418.400	10.067	13.400

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	FALL VALUES MEAN TOTAL P	FALL VALUES MEAN DISS P	FALL VALUES MEAN INORG N	ALL VALUES 500-MEAN SEC	ALL VALUES MEAN CHLORA	ALL VALUES 15-MIN DO
2693	ST LOUIS RESERVOIR	0.134	0.093	1.227	462.667	5.583	8.420
2694	CRYSTAL LAKE	0.009	0.006	0.164	380.000	2.986	13.000
2695	HIGGINS LAKE	0.007	0.005	0.058	268.500	1.043	9.400
2696	HOUGHTON LAKE	0.018	0.008	0.136	420.833	9.217	8.200
2697	THOMPSON LAKE	0.043	0.029	0.436	407.889	11.967	14.800
2698	PERE MARQUETTE LAKE	0.032	0.024	0.346	448.667	11.833	8.600
2699	STRAWBERRY LAKE	0.069	0.050	0.567	419.800	11.117	13.600

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	ALL VALUES: MEAN TOTAL P	ALL VALUES: MEAN DISS P	ALL VALUES: MEAN INORG N	ALL VALUES: SUR- MEAN SEC	ALL VALUES: MEAN CHLOPA	ALL VALUES: IS- MIN OD	INDEX NO
2680	HOLLOWAY RESERVOIR	46 (16)	43 (15)	17 (6)	57 (20)	60 (21)	63 (22)	286
2681	CARO RESERVOIR	29 (10)	54 (19)	0 (0)	3 (1)	49 (17)	54 (19)	189
2682	BOARDMAN HYDRO POND	97 (34)	97 (34)	69 (24)	91 (32)	94 (33)	97 (34)	545
2683	ALLEGAN LAKE	20 (7)	31 (11)	31 (11)	6 (2)	29 (10)	40 (14)	157
2686	BANTON LAKE	23 (8)	20 (7)	14 (5)	29 (9)	14 (5)	3 (1)	103
2689	BELLEVILLE LAKE	26 (9)	37 (13)	20 (7)	11 (4)	11 (4)	74 (26)	184
2610	BETSIE LAKE	77 (27)	77 (27)	80 (28)	17 (6)	86 (30)	94 (33)	431
2613	BRIGHTON LAKE	31 (11)	23 (8)	34 (12)	34 (12)	0 (0)	90 (31)	212
2617	LAKE CHARLEVOIX	91 (32)	91 (32)	83 (29)	94 (33)	89 (31)	60 (21)	508
2618	LAKE CHEMUNG	49 (17)	71 (25)	94 (33)	86 (30)	46 (16)	11 (2)	357
2621	CONSTANTINE RESERVOIR	71 (25)	83 (29)	40 (14)	29 (9)	3 (1)	90 (31)	316
2629	FORD LAKE	34 (12)	29 (10)	11 (4)	29 (9)	37 (13)	23 (8)	163
2631	FREMONT LAKE	0 (0)	0 (0)	23 (8)	54 (19)	9 (3)	11 (2)	97
2640	JORDAN LAKE	11 (4)	11 (4)	6 (2)	69 (24)	26 (9)	0 (0)	123
2643	KENT LAKE	57 (20)	69 (24)	63 (22)	46 (16)	6 (2)	36 (12)	271
2648	LAKE MACATAWA	9 (3)	14 (5)	3 (1)	0 (0)	23 (8)	43 (15)	92
2649	MANISTEE LAKE	80 (28)	74 (26)	77 (27)	46 (16)	83 (28)	46 (16)	403
2659	MUSKEGON LAKE	37 (13)	40 (14)	54 (19)	60 (21)	69 (24)	11 (2)	271
2665	PENTWATER LAKE	69 (24)	63 (22)	51 (18)	66 (23)	31 (11)	11 (2)	291
2671	RANDALL LAKE	6 (2)	6 (2)	43 (15)	23 (8)	20 (7)	86 (30)	184
2672	ROGERS POND	74 (26)	66 (23)	86 (30)	63 (22)	77 (27)	51 (18)	417
2673	RUSS RESERVOIR	60 (21)	57 (20)	57 (20)	9 (3)	63 (22)	79 (28)	325
2674	SANFORD LAKE	86 (30)	80 (28)	74 (26)	20 (7)	43 (15)	71 (25)	374
2683	THORNAPPLE LAKE	54 (19)	46 (16)	9 (3)	51 (18)	40 (14)	69 (17)	249
2685	UNION LAKE	40 (14)	26 (9)	26 (9)	37 (13)	34 (12)	79 (28)	242
2688	WHITE LAKE	66 (23)	60 (21)	66 (23)	80 (28)	74 (26)	31 (11)	377
2691	HONA LAKE	3 (1)	3 (1)	37 (13)	43 (15)	17 (6)	20 (7)	123
2692	LONG LAKE	14 (5)	9 (3)	46 (16)	77 (27)	66 (23)	27 (9)	239

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	FALL VALUES: MEAN TOTAL P	FALL VALUES: MEAN DISS P	FALL VALUES: MEAN INORG N	ALL VALUES: 500-MEAN SEC	ALL VALUES: MEAN CHLORA	ALL VALUES: 15-MIN DO	INDEX NO
2693	ST LOUIS RESERVOIR	17 (6)	17 (6)	29 (10)	14 (5)	83 (29)	69 (24)	229
2694	CRYSTAL LAKE	89 (31)	89 (31)	89 (31)	89 (31)	91 (32)	36 (12)	483
2695	HIGGINS LAKE	94 (33)	94 (33)	97 (34)	97 (34)	97 (34)	57 (20)	536
2696	HOUGHTON LAKE	83 (29)	86 (30)	91 (32)	71 (25)	71 (25)	79 (26)	481
2697	THOMPSON LAKE	51 (18)	49 (17)	60 (21)	83 (29)	51 (18)	11 (2)	305
2698	PERE MARQUETTE LAKE	63 (22)	51 (18)	71 (25)	49 (17)	54 (19)	66 (23)	354
2699	STRAWBERRY LAKE	43 (15)	34 (12)	49 (17)	74 (26)	57 (20)	27 (9)	284

TRIBUTARY FLOW INFORMATION FOR MICHIGAN 2/3/75

LAKE CODE 2693 ST LOUIS RESERVOIR

TOTAL DRAINAGE AREA OF LAKE(SQ MI) 311.00

TRIBUTARY	SUB-DRAINAGE AREA(SQ MI)	NORMALIZED FLOWS(CFS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
2693A1	311.00	185.00	232.00	459.00	423.00	270.00	166.00	99.00	84.50	101.00	127.00	174.00	181.00	208.18
2693A2	286.00	176.00	221.00	436.00	402.00	256.00	158.00	94.10	80.50	96.20	121.00	166.00	172.00	197.97
2693ZZ	25.00	9.00	11.00	22.00	20.00	13.00	8.00	5.00	4.00	5.00	6.00	8.00	9.00	9.99

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 311.00
SUM OF SUB-DRAINAGE AREAS = 311.00
TOTAL FLOW IN = 2498.80
TOTAL FLOW OUT = 2501.50

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2693A1	10	72	243.00	28	567.00				
	11	72	295.00						
	12	72	288.00	1	256.00				
	1	73	714.00	19	1420.00	30	478.00		
	2	73	273.00	19	215.00				
	3	73	786.00	20	781.00	30	730.00		
	4	73	648.00	26	479.00				
	5	73	502.00	24	306.00	31	785.00		
	6	73	356.00	26	198.00				
	7	73	166.00	27	208.00				
	8	73	181.00	31	99.00				
	9	73	99.00						
	10	73	127.00	15	136.00				
2693A2	10	72	231.00	28	540.00				
	11	72	281.00						
	12	72	274.00	1	244.00				
	1	73	680.00	19	1350.00	30	455.00		
	2	73	260.00	19	205.00				
	3	73	749.00	20	744.00	30	695.00		
	4	73	617.00	26	456.00				
	5	73	478.00	24	291.00	31	748.00		
	6	73	339.00	26	189.00				
	7	73	158.00	27	198.00				
	8	73	172.00	31	94.00				
	9	73	94.00						
	10	73	121.00	15	130.00				

TRIBUTARY FLOW INFORMATION FOR MICHIGAN 2/3/75

LAKE CODE 2693 ST LOUIS RESERVOIR

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2693ZZ	10	72	12.00						
	11	72	14.00						
	12	72	14.00						
	1	73	34.00						
	2	73	13.00						
	3	73	37.00						
	4	73	31.00						
	5	73	24.00						
	6	73	17.00						
	7	73	8.00						
	8	73	9.00						
	9	73	5.00						
	10	73	6.00						

61

STORET RETRIEVAL DATE 75/02/04

269301
43 24 48.0 084 36 42.0
ST LOUIS RESERVOIR
26 MICHIGAN

11EPALES 2111202
3 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/14	17 35	0000	23.1	8.6	28	2000	7.30	185	0.240	0.830	0.530	0.460
72/09/17	14 45	0000			44	1000	7.40	199	0.960	0.650	0.307	0.248
	14 45	0004	21.0	6.6		1025	7.38	192	0.860	0.680	0.319	0.243
72/11/14	17 15	0000			42	890	7.80	228	1.390	0.460	0.265	0.199
	17 15	0004	4.0	11.5		890	7.80	159	0.280	0.060	0.016	0.009

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/14	17 35	0000	19.1J
72/09/17	14 45	0000	1.0J
72/11/14	17 15	0000	1.2J

J VALUE KNOWN TO BE IN ERROR

STORET RETRIEVAL DATE 75/02/04

269302
43 24 30.0 084 37 12.0
ST LOUIS RESERVOIR
26 MICHIGAN

11EPALES
3

2111202
0005 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/14	18 50 0000		21.9	10.4	24	2100	7.38	193	0.210	0.310	0.790	0.550
72/09/17	15 00 0000		19.8	7.5	36	595	8.03	232	0.900	0.230	0.139	0.104
72/11/14	17 30 0000				50	590	7.90	212	1.280	0.210	0.120	0.072

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/14	18 50 0000		10.5J
72/09/17	15 00 0000		1.0J
72/11/14	17 30 0000		0.7J

J VALUE KNOWN TO BE IN ERROR

STORET RETRIEVAL DATE 75/02/04

2693A1 LS2693A1
43 24 30.0 084 36 30.0
PINE RIVER
26 15 ALMA
O/ST LOUIS RESERVOIR
1ST CITY BRDG BELO DAM IN ST LOUIS
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/28	09 10		0.770	2.560	0.460	0.040	0.230
72/12/01	09 15		0.230	2.305	0.054	0.008	0.019
73/01/19	16 00		1.440	1.980	0.315	0.120	0.330
73/01/30	09 30		1.600	1.470	0.280	0.110	0.240
73/02/19	13 40		1.480	3.900	0.760	0.176	0.420
73/03/20	09 00		1.280	0.780	0.138	0.070	0.770
73/03/30	13 20		1.260	1.500	0.220	0.105	0.250
73/04/26	13 20		0.810	1.540	0.290	0.160	0.360
73/05/24	14 00		0.650	1.600	0.380	0.168	0.375
	15 00		0.690	0.720	0.044	0.019	0.035
73/05/31	12 50		0.680	3.000	0.240	0.087	0.160
73/06/26	09 20		0.430	2.700	0.720	0.147	0.490
73/07/27	13 00		0.250	1.470	0.168	0.019	
73/08/31			0.260	1.950	0.750	0.610	0.790
73/10/15	14 15		0.350	1.300	0.630	0.360	0.525

STORET RETRIEVAL DATE 75/02/04

2693A2 LS2693A2
43 22 30.0 084 39 30.0
PINE RIVER
26 15 ALMA
1/ST LOUIS RESERVOIR
STATE ST BRDG BELO DAM IN ALMA
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/28	08 40		0.510	1.260	0.073	0.017	0.030
72/12/01	09 40		0.250	1.670	0.610	0.160	0.460
73/01/19	16 10		1.400	1.320	0.176	0.085	0.160
73/01/30	09 15		1.640	0.680	0.036	0.016	0.020
73/02/19	14 00		1.240	3.400	0.140	0.014	0.020
73/03/20	09 25		1.440	0.560	0.027	0.014	0.025
73/03/30	13 10		1.300	1.400	0.078	0.015	0.080
73/04/26	13 00		0.680	0.910	0.027	0.012	0.040
73/05/31	13 05		0.540	2.500	0.210	0.022	0.050
73/06/26	09 00		0.440	1.600	0.198	0.019	0.050
73/07/27	13 10		0.273	2.000	0.730	0.320	0.520
73/08/31			0.220	0.540	0.168	0.028	0.060
73/10/15	14 00		0.300	0.650	0.066	0.016	0.040

STORET RETRIEVAL DATE 75/02/04

269350 PR269350 P009710
43 22 30.0 084 39 00.0
ALMA
26 15 ALMA
O/ST. LOUIS RESERVOIR
ST. LOUIS RESERVOIR
11EPALES 2141204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
73/01/29	00 00								
CP(T)-			2.600	18.000	2.000	13.000	26.000	2.690	3.000
73/01/29	08 00								
73/02/27	00 00								
CP(T)-			2.300	22.000	2.200	8.400	12.500	2.640	2.950
73/02/27	08 00								
73/03/27	00 00								
CP(T)-			2.900	13.000	0.390	7.600	10.000	2.450	3.270
73/03/27	08 00								
73/04/26	00 00								
CP(T)-			2.300	11.700	0.092	13.100	17.000	2.540	2.910
73/04/26	08 00								
73/05/24	00 00								
CP(T)-			2.600	15.500	1.100	6.450	9.870	2.450	2.740
73/05/24	10 00								
73/07/29	00 00								
CP(T)-			1.380	16.800	5.800	2.700	8.840	1.620	1.980
73/07/29	08 00								
73/08/27	00 00								
CP(T)-				18.000	3.960	19.000	26.000	1.970	2.040
73/08/27	10 00								
73/09/25	00 00								
CP(T)-			1.600	23.100	9.200	13.700	19.500	1.800	1.740
73/09/25	10 00								
73/10/31	00 00								
CP(T)-			2.200	20.000	3.600	8.500	14.000	2.510	1.900
73/10/31	10 00								
73/11/28	00 00								
CP(T)-			2.300	15.000	0.120	4.600	9.450	2.910	1.860
73/11/28	10 00								